Prioritization and coordination of regional and local (preserve) monitoring -Group 1 Final Report
October 26, 2010

San Diego Dahlem Conference

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Introduction

How do we ensure that the San Diego Regional Preserve System is effectively managed across jurisdictional boundaries and ecological scales? Is it possible to monitor at the reserve level and integrate these efforts so they are meaningful for the preserve system and ecoregion? This paper addresses different approaches to monitoring, how monitoring protocols can address ecological variability at different spatial scales, and how the results of the monitoring could answer questions across time. It is essential to focus on collecting biologically meaningful data that can be utilized to inform management actions at various scales. The primary focus of monitoring efforts must be to inform management actions and secondarily to meet regulatory requirements. In some cases, both goals may be achieved with the same data. This prioritization will help ensure that available resources are allocated for actions that benefit the covered species and the ecosystems on which they depend rather than utilizing limited monitoring resources to collect data primarily to allow agencies and jurisdictions to check-off regulatory requirement.

Background

The South Coast Ecoregion falls within the California Floristic Province, a global biodiversity hot spot (Myers et al. 2000). Rapid urban development in the region has led to the loss and fragmentation of natural habitats, resulting in an unusually high number of rare, threatened and endangered plant and animal species in southern California (Dobson 1997). In the early 1990s it was recognized that biological resources were not being addressed at the proper scales. Project-by-project review and regulatory permitting produced highly fragmented landscapes with no long-term plan for maintaining the incredible biodiversity. Local jurisdictions, environmental organizations, and the resource agencies began working together to develop a different way of planning to conserve sensitive species, their natural habitats and overall biodiversity. It was acknowledged that planning needed to be implemented regionally, similar to other infrastructure such as roads and sewer, rather than parcel-by-parcel.

The coastal California gnatcatcher (*Polioptila californica californica*) was listed as federally-threatened by the USFWS in 1993 (USFWS 1993), which provided added incentive and a regulatory handle to start planning for open space at a regional scale. Concurrent with the listing of the gnatcatcher by the USFWS, the State produced Conservation Guidelines and other documentation to support the Southern California Coastal Sage Scrub Natural Communities Conservation Program (NCCP) (CDFG 1993). The gnatcatcher is one of the flagship species for the South Coast Ecoregion in southern California. The other two target species identified at that time were the coastal cactus wren (*Campylorhynchus brunneicapillus sandiegensis*) and the orange-throated whiptail (*Aspidoscelis hyperythrus beldingi*). The geographic area of the coastal sage scrub community was selected as a pilot program for the first NCCPs. The biological goals of the Coastal Sage Scrub NCCP are to (1) conserve viable populations of California's native animals, plants, and their habitats, and (2) identify a scientifically justified system of coastal sage scrub habitat areas to be managed for ecological values and the long-term protection of multiple species of interest (NCCP MOU 1991). Although coastal sage scrub extends beyond the ecoregion, the planning area was initially limited to Orange, Riverside, San Diego counties and the Pales Verdes Peninsula in southern Los Angeles County. This area is isolated from the coastal sage scrub habitat in the more north-westerly areas of Los Angeles and Ventura Counties by urban areas and therefore did not extend further north; the initial focal area captured the overlapping distributions of the gnatcatcher, cactus wren and whiptail. The three target species were used to help focus the initial planning efforts, but only cactus wren and gnatcatcher continue to be a in the group of focal species are for management and monitoring during the implementation phase for the San Diego NCCPs.

Figure 1: South Coast Ecoregion

There was general consensus among the stakeholders that planning should be done on a "regional" scale. A Scientific Review Panel was convened to draft conservation guidelines for the southern California coastal sage scrub NCCP area. The planning area was divided into subregional planning areas based on political jurisdictions, landscape features, and biological parameters for planning purposes. The NCCP plan in Orange County focused primarily on coastal sage scrub habitat and associated species while the plans in Riverside and San Diego Counties included all habitats with each planning boundary. In San Diego County the decision was made to develop plans at the multi-jurisdictional level but to implement them at the It made jurisdiction level utilizing each entities land use authority. This has resulted in preserve management responsibilities being dispersed amongst various entities and jurisdictions with a collective responsibility to achieve the regional preserve system biological goals.

Since significant portions of the preserve system have been assembled, there is now a focus on how to adaptively manage and monitor the preserves as a system rather than as individual preserves. An approach to dealing with both temporal and spatial scales needs to be clearly articulated for the monitoring and adaptive management. While maps can be used to show the juxtaposition of conserved land parcels and associated habitats, effective and appropriate management and monitoring will require those responsible for management and monitoring to utilize a more holistic approach. How to effectively manage and monitor the San Diego regional preserve system across jurisdictional boundaries and at appropriate scales is the daunting challenging currently facing us?

Issues/challenges that have to be addressed include species and habitat management and monitoring across jurisdictional boundaries, coordinated data analysis, utilizing available funding efficiently and effectively, and clear identification of tasks and acceptance of associated responsibilities by specific entities. How are threats and stressors that affect habitats and species at multiple scales going to be addressed by funding decision makers and land managers that may not have the authority for actions at the appropriate scale? What should an individual preserve manager monitor to help inform their management at the preserve scale? Figure 2 from Atkinson et al (2004) illustrates how monitoring responsibilities may be implemented differently for species, natural communities, and threats, depending on the geographic scale at which they occur; whether they are widespread, operate over multiple scales, or are confined to a small spatial extent.

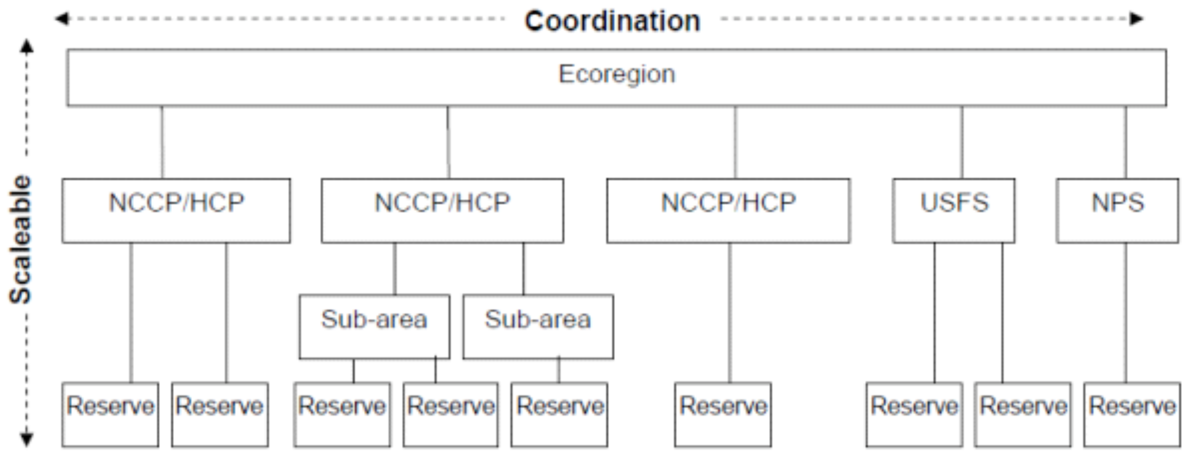

Figure 2. Monitor at the appropriate geographic scale. Progress toward meeting the objectives of regional conservation plans should be monitored at the appropriate geographic scale. The status of essentially immobile species can be addressed at the scale of a single reserve. Large-scale issues and wide-ranging species can only be appropriately assessed at larger scales, requiring coordinated sampling across multiple reserves and possibly non-reserve lands. In addition, if information needs to be interpreted at multiple scales, then the sampling design will need to be appropriately scaleable to address these needs.

Principles of monitoring for biological conservation

Monitoring should be purpose driven. The primary purposes for monitoring in a multi-species conservation framework are: (1) implementation (compliance) and (2) effectiveness monitoring (Atkinson et. al, 2004). Our focus is on effectiveness monitoring, which is generally defined as monitoring that generally measures status and trend of resources, status and trend of pressures (threats/stressors and effects of management actions and may also include targeted studies (Lindenmayer and Likens 2010; Atkinson et al, 2004).

Effectiveness monitoring can also help provide information managers and scientists seeking to understand mechanisms underlying population dynamics or ecological processes. Effectiveness monitoring includes targeted studies that are hypothesis driven and also intended to provide information on mechanisms underlying the measured trends (Atkinson et. al 2004)

“Question-driven” monitoring is based upon a conceptual model with a well thought out study design and provides information on underlying mechanisms (Atkinson et al 2004, Lindenmayer and Likens 2010). It is especially useful to land managers, researchers and decision makers as it has predictive capacity, allowing the comparison of management actions and an understanding of cause and effect relationships. Question-driven monitoring is often experimental in nature and provides data that reduces uncertainty in knowledge about population dynamics, ecological systems or management techniques.

Mandated or compliance monitoring generally does not detect long-term trends in species status or community processes since it is it generally focused on doing so. Mandated or compliance monitoring is often a result of perceived legal requirements and is often negotiated between the wildlife agencies and the permittees without an understanding of the spatial and temporal issues that will arise after the preserve assembly and management is initiated, a temporal problem faced by many conservation planning efforts. It is often difficult to integrate question-based monitoring framework and sampling strategies designed to gather information about factors potentially affecting the monitoring target into plan-mandated monitoring.

Effectiveness monitoring should utilize conceptual models depicting threats and natural processes predicted to affect a species or a natural community to guide development of a sampling program that incorporates collection of covariate data. These data can be used to evaluate the strength of association between metrics measured for the monitoring target and the identified threats or other processes. (Hierl et al 2005, Atkinson et al 2004 and Gross 2003)

Monitoring is a time-dependent procedure and can vary widely in how it is done. It can include both qualitative and quantitative elements, utilize sampling methods or complete counts, utilize various types of telemetry or mapping (spatially explicit and comprehensive description or quantification of landscape phenomena or properties), conducted over time.

To meet the goals of the San Diego plans, monitoring of: (1) covered plant and animal species, (2) natural communities, (3) linkages and corridors and the factors affecting the natural communities (threats/stressors), and (4) ecosystem processes is necessary. As used here, natural community monitoring includes monitoring the properties of habitats that pertain to quality, health, integrity, and/or suitability for sustaining for covered species).

Spatial and Temporal Scale Relationships

Spatial and temporal scales of ecological processes and forms, as well as measurements of such processes and forms can be characterized by grain (fineness of detail) and extent/duration (domain of coverage). The characteristic spatial and temporal grain and extent/duration requirements will vary for both regulatory and adaptive management purposes of monitoring.

There is no single appropriate scale for understanding all ecological processes and change (Levin 1992). This complicates monitoring, as it is difficult to determine the temporal and spatial scale to which a monitoring program should focus (du Toit 2010). Ecological patterns vary depending upon the scale, as do the underlying mechanisms that drive these patterns (Levin 1992). While it is important to identify and describe these ecological patterns or processes, in order to understand the factors responsible for these patterns will require well-designed experimental studies. Typically, question-driven monitoring, often in the form of experimental studies, occurs at a small-scale, making it difficult to generalize results (Lindenmayer and Likens 2010).

In designing long-term monitoring programs it is important to consider the target of monitoring and the appropriate scale. It may be that several different scales are considered or tested before a monitoring plan is finalized (du Toit 2010). For instance, a monitoring program devised for an endemic plant species occurring at a few well-defined locations will differ considerably from a monitoring program for a widespread species or plant community that is distributed over a large area with highly variable environmental conditions (see Figure 3). Therefore the first step in developing a long-term monitoring program is to develop clear, measurable conservation goals and objectives for each species and habitat covered under the plan (Atkinson et al. 2004, Hierl et al. 2007).

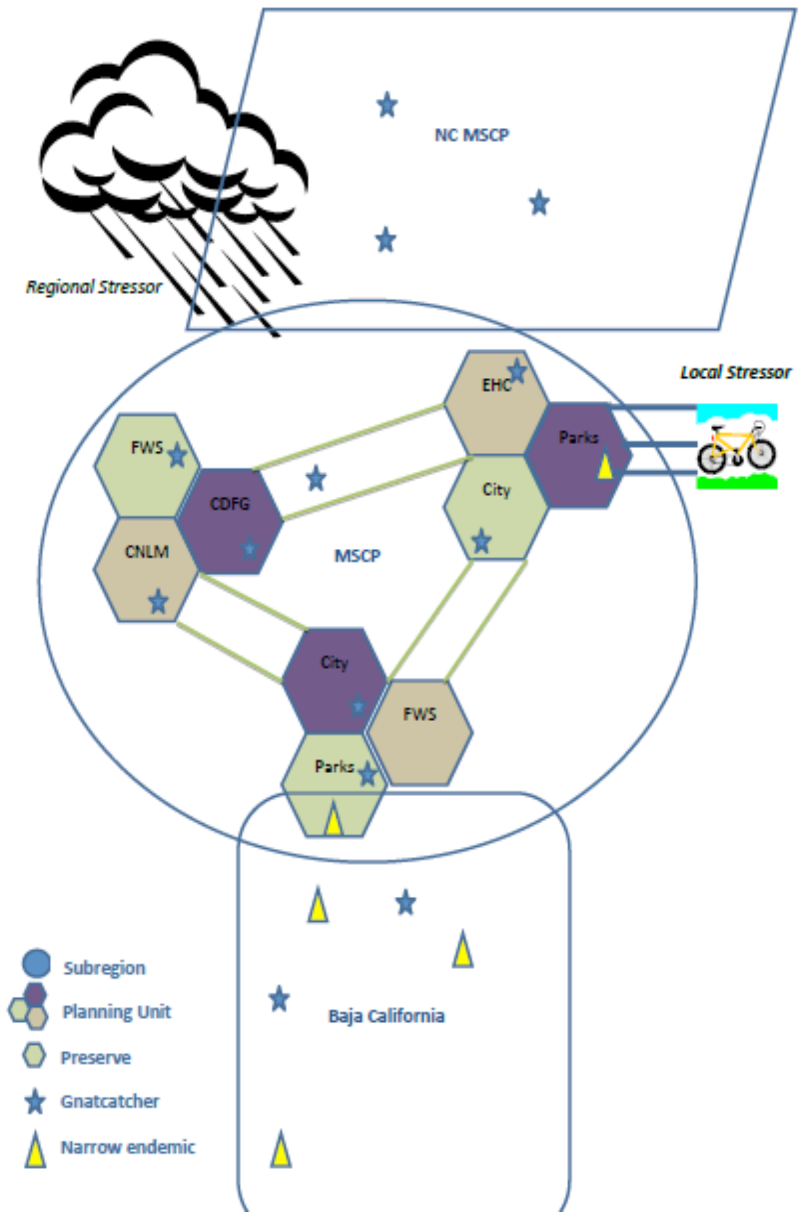

Figure 3. Examples of spatial scales to consider for stressors, species and preserves

Hierarchical Approach to Monitoring

In developing a long-term monitoring program it may be appropriate to take a hierarchical approach. The first step is to employ question-driven effectiveness monitoring that utilizes conceptual models to identify the covariate data that should be collected to help understand changes in community processes, threats and natural environmental drivers. When a downward trend in population or adverse impacts to community processes are detected over a sustained period or in a very sharp decline over a short time period, then this could trigger adaptive management actions (including appropriate monitoring) to reverse the detected change or the implementation of targeted question driven monitoring designed to more fully understand the causes underlying the downward trend. Adaptive management actions may need to incorporate multiple experimental trials to distinguish the effectiveness of alternative management actions. The regional monitoring entity in partnership with the stakeholders and land managers should work together to identify when adaptive management or targeted studies should be employed to better understand causal relationships underlying trends or to determine the efficacy of alternative management actions. The group should also participate in developing the appropriate questions and defensible study designs for adaptive management actions or targeted studies.

Spatial Scale

Regional effectiveness monitoring is primarily oriented toward understanding status and trend of covered species at the reserve system and regional levels. The key is to sample populations in a spatial manner that ensures consistent and comparable estimates over time (Deutschman et al. 2005). This is more likely to be achieved when the same, well-trained crews are conducting the monitoring. The spatial sample design should ensure temporal consistency, minimize effort, and satisfy statistical validity. The design should be based on knowledge of habitat relationships, such that habitat areas of high probability of presence could be sampled more intensively than less populated areas if it is appropriate to stratify the sampling base on species density or habitat quality. The temporal frequency of species monitoring should be based on knowledge of population dynamics and time scales of associated stressors. Spatial-temporal sampling schemes will be different for various covered species.

Species Monitoring

Monitoring plans should be developed for each species or group of species to enable tracking of population trends and distribution patterns over a long time frame. The temporal frequency of sampling will depend on the natural annual variation in population abundance and whether the species is prone to cyclic population dynamics. Annual variation in climate, in particular the timing and amount of annual precipitation, can affect populations through influences on productivity and survivorship. It may be necessary to sample each species annually for a period of five or more years to determine normal fluctuations in population abundance. Once this baseline of population dynamics is determined, a sampling scheme can be developed to detect long-term population trends or abrupt changes in population that may warrant targeted studies and management actions.

The spatial scale of sampling will depend largely on the species overall distribution, the scale of the territory or home range, and whether the species is clustered or more evenly distributed throughout the reserve system. An important consideration when designing a spatial sampling strategy is the vegetation communities that the species tends to occur in and the extent to which these communities are distributed across the landscape. Developing a strategy to sample species populations across space will be a trade-off in collecting information that describes long-term trends in distribution patterns and abundance versus collecting sufficient data to be relevant for management at the preserve-scale. For widespread species, spread out across the reserve system, it will be important to sample at each preserve with the potential to support the species. The number of surveys at each preserve will depend on the amount of potentially suitable habitat. Care should be taken to design a sampling strategy that samples suitable habitat across the landscape either randomly or in a stratified manner, based on habitat characteristics.

Spatially-explicit habitat suitability models or niche models provide powerful tools for monitoring conserved species (Scott et al. 2002, Elith et al. 2006, Rotenberry et al. 2006). Habitat suitability models are created using abundance, density, or presence-absence data for the species of interest (Guisan and Zimmerman 2000, Elith et al. 2006, Preston and Rotenberry 2006). Improved Geographical Information Systems (GIS) software and digital environmental layers and new modeling techniques allow the creation of multivariate species' habitat models over a large geographic area. These regional models incorporate hypotheses about a species' occurrence relative to environmental conditions across the landscape of interest. Habitat suitability models are particularly useful in identifying areas to survey for rare species when the spatial distribution of that species is not well described or known (Preston and Rotenberry 2007, Franklin et al. 2009). Using habitat models to identify potential sampling locations facilitates a more efficient use of survey resources by targeting sampling to those areas where the species is most likely to occur. Once additional species location data are collected, they may be used to refine the models as needed and increase predictive power in targeting surveys to new areas where the species is likely to occur.

Habitat models can also be used to predict changes in species distribution and abundance in reserve systems as a result of changing environmental conditions, such as climate change (Hannah et al. 2005, Preston et al. 2008, Franklin 2010, Lawson et al. 2010). Modeling approaches are being developed that incorporate other threats to species, such as urbanization and altered fire regimes (Syphard and Franklin 2009, Lawson et al. 2010). These threats can be incorporated into future climate scenarios to predict where species might occur in the future under global change. Output from these models can be used to design spatial sampling strategies that detect whether species are undertaking distributional shifts in response to environmental change.

Species versus Community Sampling and Collection of Environmental Data

It may be possible to monitor groups of species and more efficiently use limited monitoring resources. For example, to sample reptiles and amphibians pit fall trapping is often the best means to obtain samples and this allows the collection of data on a diverse suite of species. Riparian birds are another example of where point count surveys of the entire bird community are effective at collecting information on several species of conservation concern as well as potential threat species (e.g., Brown-headed Cowbird and European Starling). Whenever, sampling a single species or a community, it is important to collect information on habitat characteristics including threats to species. These data can be categorized at each survey location during sampling and some types of data can also extracted from GIS digital layers. Data collected on habitat characteristics and levels of threat can be included as covariates in models that identify species' habitat relationships in relation to occupancy patterns (e.g., Winchell and Doherty 2008).

Most species and community sampling surveys should be undertaken by the regional monitoring entity, as this allows sampling across the reserve system in a consistent manner with a group of trained biologists. In many cases there may be regulatory permits and specialized training requirements in order to survey for a particular species. Preserve managers may need to conduct their own surveys to gather information on impacts to sensitive species populations from infrastructure projects or recreation activities. These surveys would be independent of these long-term trend surveys, which are unlikely to sample each preserve at the spatial resolution necessary to evaluate impacts. It is important to have protocols that reserve managers can use that ensure data collected are compatible with data collected by the regional monitoring entity.

Habitat Monitoring

Monitoring for adaptive management purposes should be oriented towards monitoring habitat conditions and characterization of ecosystem variability associated with stressors. While managers may be interested in spatial and temporal variability of covered species populations within their reserve, the spatial scale of their preserve may preclude obtaining such data with any statistical reliability. Because of this spatial issue, land their adaptive management actions may have to be primarily focused on habitat condition and its response to stressors. Knowledge of habitat change enables managers to take actions such as removing invasive species, restricting access to habitat by humans and their domestic animals and recreational vehicles, habitat restoration, change management priorities or attempting to control biophysical properties (e.g., water and nutrients) that limit or enhance ecosystem functioning. While most management currently occurs at the individual preserve level new programs are encouraging land managers to implement management at the preserve system level, so the spatial extent of habitat monitoring may need to occur at multiple scales. However, as with species monitoring, the same habitat monitoring protocols should be utilized regardless of scale, and data sets should be consistent and comparable across reserve system and regional scales to enable assessment of habitat health over large areal extents. Four general approaches to habitat monitoring include: (1) field surveys of floristic species composition and/or soil properties, (2) monitoring of stressor either directly or indirectly (3) remote sensing based mapping of vegetation life-form cover fractions and/or vegetation structure, and (4) integration of one or more of these approaches. The three disparate approaches (1-3 above) are summarized in Table 1.

One approach to monitoring habitat condition is to sample plant and/or animal species composition and/or soil properties within plots, along transects, or through some combination of plots, transects or other methodologies. The advantage of this approach is that very detailed estimates of plant species cover, exotic and invasive species density and/or stature/structure, as well as soil or water properties such as bulk density, moisture and organic content, ph, dissolved oxygen etc can be obtained. This approach is suitable for obtaining species community data at both a coarse and fine scale. The disadvantage is that such measurements require a great deal of person power and significant effort may be needed to develop a sampling design so the data can be used to characterize the reserve or reserve system. This can be due to site-specific influences associated with land use history, stressor variability, and ecosystem properties (e.g., associated with topographic position). While it may be difficult to extrapolate temporal trends of species occupancy and/or cover to other locations, the aggregation of plot level estimates at the reserve system and regional scales is likely to capture variations due to regional preserve system and regional-scale stressors such as fire, drought, climate change, and air pollution. One approach for increasing representativeness is the use of panel analysis (Urquhart and Kincaid 1999).

Table 1: Three approaches to monitoring habitat condition (adapted from Hamada et al, accepted)

Method	Community Type Mapping	Life-form Cover Fraction Estimates	Field-based Surveys
Biological Scale	Community type	Life-form type Generally coarse filter	Species/fine to coarse filter depending on methodology
Spatial Scale	Coarse (e.g. >30 m)	Moderate	Fine (e.g. 10 m)
Spatial Comprehensiveness	Wall-to-wall	Wall-to-wall	Sampling plots
Cost	Expensive	Inexpensive	Moderately expensive
Temporal frequency	Decadal	1 to 3 years	Depends on concerns about interannual variation

Remote sensing approaches to monitoring habitat condition enable spatially-explicit and comprehensive estimation of more general compositional or structural properties of vegetation and land cover (Coulter and Stow 2009; Stow et al. 2008). The two properties of vegetation of likely interest for multiple-species conservation in the NCCP planning region that are most amenable to remote sensing are life-form cover (e.g., shrub, sub-shrub, herbaceous and bare) derived from multispectral image data (Hamada et al., accepted) and vegetation structure (i.e. height and density) derived from scanning LIDAR data (Riaño et al. 2007). The advantage of this monitoring approach is the complete ("wall-to-wall") sampling characteristics and the relatively low cost of data collection over large areas, enabling regular (interannual) and comprehensive monitoring of habitat conditions. Life-form cover or bare fraction can be estimated to within an accuracy of about 10% (Hamada et al. submitted; Witzum and Stow 2004) The primary disadvantage is that only a few species can be identified definitively, the cover estimates have lower accuracy and greater uncertainty than field-based estimates, and because of its coarse filter, may not provide data that informs year-to-year management decisions.

A third monitoring approach is to map and digitally encode vegetation community type units and periodically update GIS layers depicting community type maps, to determine changes associated with type conversion, fire and air pollution. Changes in land use and habitat loss would also be detected and could be compared with the data available from the conserved lands database. Mapping and updating are based on high spatial resolution remotely sensed ortho-imagery, primarily used in conjunction with field plot sampling and field reconnaissance. An example is the approach being implemented by SANDAG and Cal Fish & Game that is based on the Keeler-Wolf classification system and mapping protocols (Evans and San 2005). Updates are likely to be made on a decadal basis and conducted through image change analysis followed by detailed field reconnaissance. The actual update frequency depends on the spatial and temporal frequencies of stressors (e.g. wildfire frequency and land use changes) that can alter community types. The disadvantage of this approach is that habitat conditions may change within mapped vegetation community units and not be detected or quantified.

Habitat Connectivity Monitoring

As habitat becomes fragmented, populations occupying larger, contiguous patches of habitat become more isolated in the remaining habitat patches. Smaller populations are at greater risk of extirpation due to stochastic and anthropogenic events (e.g. chance demographic and genetic events, catastrophes, and environmental variability, introduction of exotic species and disease, etc.) (Shaffer 1981) Connectivity between habitat patches can help reduce the risks to species and populations from stochastic and anthropogenic effects through:

- Access to resources via within-home-range movements, migration, etc.
- Demographic exchange (dispersal, recolonization, demographic rescue, etc.)
- Gene flow (including potential for adaptation and evolution)
- Maintenance of ecological function including food web dynamics, trophic interactions, and species movement among core areas and habitat patches
- Providing opportunities for shifts in species geographic ranges in response to environmental change such as climate change

Maintaining connectivity amongst core areas and to lands outside of the plan areas is essential for maintaining the biodiversity of the preserve system and resilience of species and natural communities in the San Diego region.

Knowing if an individual of a species has traversed a chokepoint is helpful for addressing potential connectivity at a chokepoint but only allows for inferences regarding the functionality of the linkage as a whole. Recent research utilizing genetics has demonstrated that merely documenting animal movement past a chokepoint does not necessarily result in functional connectivity (Riley et. al 2006). To meet the connectivity goals of the plans, understanding if and how core areas are functionally connected is critical. Do the plans need to manage for groups of a species that are part of a larger population or groups of a species that are isolated from nearby groups? The current level of connectivity is important for informing management decisions for a wide variety of species, including those species that move on the ground, along or within water columns, through the air or by hitchhiking on other species. While most connectivity is achieved by an organism moving from one area to another, in plants, functional connectivity may also be the result of pollen moving between populations. Connectivity monitoring utilizes various approaches including banding, tracking, camera traps, genetic analysis, stable isotope analysis, disease or telemetry. The question and species being addressed generally determine the monitoring methods utilized for connectivity monitoring studies.

Threats and Stressors

Defining Spatial Scale by Threat

In San Diego County, natural populations are faced with myriad threats that operate at different levels of intensity and spatial and temporal scales. Hierl et al. (2005) recommended that any monitoring plan designed for the purpose of informing future management activities explicitly consider threats including the spatial and temporal scale of the threat/stressor.

Regan et al (2006) identified a list of stressors that were utilized as part of their risk assessment for the 85 MSCP Covered Species. They identified three species monitoring risk groups, with Risk Group 1 being the highest priority for species population monitoring. While monitoring populations may provide important information regarding status and trend, it does not provide a full picture of why a population may be changing and therefore what the management focus should be (e.g. controlling predation, controlling invasive species, fuels modification to reduce the severity of fire, etc.). Collecting data on covariates based on hypotheses derived from a conceptual model can help us better understand what environmental factors may be changing over time, but the covariate data collected must be temporally and spatially appropriate and should be related to threat/stressors. Direct monitoring of threats/stressors will also require consideration of both temporal and spatial scales as well as a specie's and/or natural communities' response at those same temporal and spatial scales.

Table 2. Matrix showing the temporal and spatial scales of threats/stressors for a sample set of species.

	Recreation				Exotic Species	Wildfire		Pesticide or Poisons		Roads	
	Hiking	Trail Riding	Biking	Dogs with hikers		Frequency	Intensity	Direct	Indirect	Direct Mortality	Fragmentation
Golden Eagle	LT	ST	ST	LT			LT		MT		
BUOW				MT					LT		
CAGN			MT		MT	LT	MT				
Cactus Wren					MT	LT	LT				
SD Thornmint					LT	ST					
SD Ambrosia					LT	ST					
Mountain lion						ST	LT		LT	LT	
Pond turtle				MT	LT	LT	LT			LT	LT

ST – short term, less than 5 years
MT – moderate term, 5 to 10 years
LT – long term, more than 10 years

Monitoring of Stressors and Threats

Monitoring of stressors and threats that may affect covered species directly or indirectly by modifying habitat condition may also be desirable. Some stressors can be observed and recorded directly, while for others only the immediate landscape and biological impacts of such stressors can be observed and monitored over time. Stressors of substantial importance within San Diego County included non-native species (both plants and animals, terrestrial and aquatic), human use of preserves (both legal and illegal), changes in vegetation due to urban runoff, wildfire, drought, climate change, air pollution, hydrologic changes in watershed, changes in the water table or stream flow due to changes in dam operations, erosion and mass wasting. The latter is both a stressor of species and their habitats and an ecological factor influenced by other stressors.

Allocating Effort across Spatial Strata

Hypothesis based and conceptual model driven effectiveness monitoring is difficult. It requires multiple human structures (cities, counties, NGOs, and others) to develop monitoring programs that fit with the temporal and spatial scales at which ecological systems need to be monitored and adaptively managed.

Human Structures: Who should do what?

The appropriate entity to conduct monitoring activities will depend on a number of considerations. Some of these include the identity of the species, community or ecosystem that is being monitored; the type of attributes to be measured; the spatial extent across which monitoring will be conducted; the temporal frequency and duration of monitoring activities; the requirement for specialized expertise or regulatory permits; and the resources available to entities to carry out the monitoring. At the local scale, reserve managers may be very effective at monitoring specific, small-scale threats or isolated populations restricted to a very limited area, whereas regional monitoring teams are most likely to be more effective in cases where the species, community, ecosystem or threat is widespread across the region, requires complicated sampling or extensive training, expertise, or regulatory permits, or is a targeted and time-consuming study. A regional monitoring entity should oversee all monitoring, from the level of the individual reserve to the entire reserve-system in order to ensure consistent protocols and training for comparable results. The regional monitoring entity should also interact with other similar entities so that monitoring efforts across the South Coast Ecoregion are comparable. This will allow for larger scale analysis encompassing all or a significant portion of the range of a species or plant community.

Ecological Structures: Harnessing what we know about variability

Southern California experiences high inter-annual climate variability, particularly in precipitation patterns. This variability has a strong effect on species, especially fecundity and mortality rates, areas occupied some species populations, and ecological processes. As such, long-term monitoring efforts may also include development of a baseline showing the natural range in responses of species, natural communities and ecosystems to this climate variability. It is important to design the monitoring program to account for natural inter-annual variability so that it can be determined when a downward trajectory is a result of a serious threat independent of the typical annual variation.

Identifying specific traits and attributes to measure can be aided by the development of conceptual models showing hypothesized relationships between anthropogenic threats and natural drivers to population dynamics of a covered species or desired attributes of a plant community or ecosystem (Atkinson et al. 2004, Hierl et al. 2007, Lindenmayer and Likens 2010).

Monitoring focused conceptual models have been developed for many of the Regan et al. (2006) risk group 1 animal species (Clark et. al 2008) and more are in preparation. Sample conceptual models for two plant communities have been developed, the coastal sage scrub plant community, and the landscape-scale upland shrub communities (Hierl et al. 2007). As adaptive management actions are considered, they should utilize these or other models. These and other models should be further developed and integrated into the monitoring program to guide decisions on which species, plant communities and ecosystems should be targeted for monitoring. These models will also help in designing monitoring methods, identifying attributes to measure, determining how often to measure and over what time-scale, and over what spatial scale measurements should be collected.

Obstacles: San Diego as a Vignette

Monitoring requires significant planning and oversight during experimental design, data collection, data analysis and reporting, and the cost associated with each task is only loosely related to the spatial scale. Szabolcs et al (2008) found that experimental design was lacking in nearly 50% (n=130) of the habitat monitoring being performed in countries within the European Union. They also found that for half of the monitoring programs reviewed, it was unclear how the data were analyzed.

Various authors (Klines et al, 2001, Marcus et al, 1995, Fitzpatrick et. al, 2009, Kercher et al, 2009, Pierce and Gutzeiller, 2007) have identified multiple monitoring program issues that need to be addressed to help assure that the monitoring data have value. They found the most common pitfalls were in monitoring programs were:

- Poor or no experimental design
- Sampling and observer biases that were often overlooked or poorly analyzed and were associated with one or more of the following:
    - Methodology/protocols
    - Temporal issues with data collection- inter and intra- annual variation
    - Lack of observer training in protocol implementation
    - Observer visual and/or auditory acuity
    - Differences in observe expertise and/or training
    - Inconsistent interpretation of protocols
    - Lack of knowledge of species/habitats being monitored
- Failure to QA/QC data quickly so consistent errors can be identified
- Delayed or no analysis of data (and revision of protocols as appropriate to improve them and reduce bias)
- Failure to understand temporal variation and control for it

Unified or Dispersed Monitoring Approach

Many of the SD monitoring efforts have been plagued by these same issues and the situation is exacerbated by the dispersed monitoring approach that has developed. Monitoring at the preserve level often occurs because a single entity with limited resources attempts to fulfill their permit obligation irrespective of the value of the data for informing management decisions or for analyzing the status and trend of a species. As a result, many of the issues/problems identified above are inadequately addressed. In addition, data collected at the preserve level and not collected as part of a larger monitoring effort, cannot be aggregated into a larger usable data set for analysis at a higher level.

Two different approaches could be used to improve the monitoring program in San Diego. One approach would be to continue the dispersed approach for preserve level monitoring, and implement a separate program for regional preserve system level monitoring. However, this approach is not cost effective nor does it address the issues identified above. An alternative approach would be to utilize a unified/single entity approach to monitoring at several spatial scales. This could result in cost savings, primarily from a significant reduction in duplicative efforts to address issues such as:

- Experimental design
- Training program development and implementation
- Observer bias evaluation
- Consistent application of protocol
- Regular feedback from multiple team members to improve implementation efficiency
- Reduction in multiple agencies having to handle and analyze data and prepare reports.

The primary obstacles to a unified approach include:

- Real and/or perceived loss control
- Difficulty in transferring monitoring funds to a single monitoring entity
- Monitoring funding deficiencies on the part of some entities
- Political issues associated with funds from one entity helping to collect monitoring data on another entity's preserves
- Political issues associated with an entity collecting data on another entity's property
- Differences in what various entities believe is important data to collect and how it should be analyzed.

Case Studies of Successful Spatial Thinking

California Gnatcatcher – A Monitoring Example

The City of Carlsbad's Habitat Management Plan (HMP) addresses a subarea of the subregional MHCP. The conservation analysis for the HMP estimates that 127 point locals of gnatcatchers will be preserved within the reserve (Carlsbad HMP 2004). Currently, each reserve manager allocates resources to "count" gnatcatchers within the preserve and document compliance with the HMP. Unfortunately these "counts" do not provide any information to the land managers regarding what, if any, management actions they should be taking, nor does it really provide any insight into the status of the gnatcatcher within the city and what changes (up or down) in numbers actually means. The Center for Natural Lands Management estimates that it and CDFG spent approximately $35,000 in 2009 to count gnatcatchers within the preserved lands in Carlsbad.

While Carlsbad was "counting" gnatcatchers, the Service, with funding from Transnet, implemented a region wide study of gnatcatcher population dynamics within conserved lands in San Diego County. This was the third survey period for the MSCP (2003, 2007, 2009). The study was designed to sample habitat across the region in order to make estimates of the size of the population within the reserve as well as to look at the potential effects from the 2003 and 2007 fires. This regional sampling will likely be conducted every three years and, if designed and implemented correctly, will monitor/detect trends in the gnatcatcher population within San Diego County Preserves. In addition, many habitat covariates were also collected and analyzed; based on these covariates, habitat can be categorized as high quality, low quality etc. If this study is accurately assessing/detecting the trend (up or down) of the gnatcatcher population, and providing insight into habitat quality, there is no need to count birds in Carlsbad. Instead local managers should monitor CSS habitat quality and only monitor gnatcatchers if there are specific disturbances or activities. Furthermore, these same habitat covariates may also be relevant to other coastal sage scrub species such as cactus wrens and whiptails.

Evaluating trends in habitat quality with vegetation monitoring by using consistent methodologies , as illustrated in Table 1, makes financial sense because it has applicability for multiple species. In this example, Carlsbad can use the cost savings from not conducting gnatcatcher surveys in order to fund the vegetation monitoring. Monitoring programs should not be conducted in a vacuum. Data on population size is of little use without the collection of complimentary data on threats and natural environmental processes to be used in covariate analysis. Variations in these variables through time and space may correspond to variation in gnatcatcher population size, providing insights into observed population trends and suggesting management actions to increase populations or abet declines. This will avoid the pitfalls of "counting for counting's sake."

Arundo – A Management Example

Within southern California riparian corridors, the spread of invasive species has been identified as one of the major threats and stressors to the system. Many species of weeds have been identified within these systems; one species in particular, giant reed (*Arundo donax*, arundo), has been the target of extensive exotic plant removal efforts. *Arundo* is a thick-stemmed plant in the grass family, resembling bamboo, growing up to 30 feet tall. It forms many-stemmed clumps, spreading from thick, knotty roots called rhizomes that grow horizontally, not downward. The root masses can spread over several acres, quickly forming large colonies that displace other plants. This highly invasive species can spread through vegetative reproduction, either from underground rhizome extension of a colony or from plant fragments carried downstream, primarily during floods, to become rooted and form new colonies (Else 1996). *Arundo* has been the biggest problem in coastal river drainages of southern California, especially in the Santa Clara, Santa Ana, San Luis Rey, Santa Margarita, Tijuana and other major and minor watersheds, where it sometimes occupies entire river channels from bank to bank (Jackson et al. 1994). *Arundo* displaces native plant species that many wildlife species, including federally endangered species (e.g., least Bell's vireo (*Vireo bellii pusillus*)), rely on for food, shelter, and reproduction. In addition, *Arundo* is highly flammable most of the year, creating a fire hazard for other vegetation, buildings, and people. Its presence can increase both the probability of wildfire and the intensity of fires once they occur. For these reasons, land managers often focus much of their effort on the removal of this species. Unfortunately, unless their preserve is located at the top of a watershed, these efforts, although well intended, may be ineffective.

In drainages where *Arundo* has established itself throughout the watershed, effective control of this species must be conducted on a watershed-wide basis. Eradication efforts should start at the top of the watershed and work downstream[1]. The local land manager with a preserve in the middle of the watershed will not control *Arundo* until the upstream source of *Arundo* has been removed.

The appropriate scale to manage *Arundo* removal is at the watershed level rather than at an individual preserve. This means coordinating with multiple land owners, including private property owners, for access and resources to control the infestation. Land managers need to

[1] There may be limited cases where it is appropriate to control *Arundo* at a local preserve to address species needs in the short term in the absence of a watershed approach.

be educated on the value of potentially spending their limited management dollars on “up stream” property they may not own or manage.

Comprehensive, region-wide monitoring of *Arundo* distributions can be achieved through integration of airborne imaging and field reconnaissance. Unlike scrubland, grassland and forest habitats, riparian zones are long and narrow, enabling aircraft platforms to follow river courses and capture the entire zone in a single swath. *Arundo* has a unique visual signature on ultra-high spatial resolution aerial color imagery and a unique spectral signature on airborne color infrared imagery for a range of spatial resolutions (Hamada et al. 2005). Field reconnaissance is needed for refinement in image-derived maps and reconciliation of individual or very small patches of *Arundo*. Pertinent imagery is often readily available from extent airborne image data sets such as the USGS NAIP program. Inexpensive and flexible aircraft platforms such as small unmanned airborne vehicles (UAVs), light sport aircraft and digital cameras are promising for low-cost *Arundo* mapping in a comprehensive manner.

Tecate Cypress – A Collaborative Approach

Tecate cypress (*Hesperocyparis forbesii*) is an endemic closed-cone cypress species restricted to southern California in the United States and northern Baja California in Mexico. This species provides an example of where monitoring and management is most effective when individual land owners and managers join efforts to share information and develop monitoring and management priorities with reserve-system monitoring and management entities encompassing the species distribution in the South Coast Ecoregion. This partnership could also be extended to a bi-national collaboration.

Within southern California there are four distinctive Tecate cypress populations in Guatay, Otay and Tecate Mountains in San Diego County and the northern Santa Ana Mountains in Orange County. Small stands and individual trees are scattered along a 150 km coastal strip in Baja California, Mexico. San Diego populations are conserved under San Diego’s MSCP, whereas the northern Santa Ana Mountain population is conserved under Orange County’s Central and Coastal Natural Community Conservation Plan (OC NCCP/HCP). Tecate cypress populations are distributed on lands owned and managed by the Bureau of Land Management (BLM), US Forest Service, Orange County Parks, and California Department of Fish and Game. Because of the small number of widely distributed populations, this species provides an example in which local land owners/managers, regional monitoring entities and scientists can come together to develop monitoring and management actions for the entire distribution of the species.

The Nature Reserve of Orange County (NROC) is responsible for coordinating and implementing monitoring and management activities for sensitive species within the OC NCCP/HCP and recently completed a Tecate Cypress Management Plan (http://www.naturereserveoc.org/projects). A representative of the BLM responsible for San Diego populations attended NROC's Tecate Cypress Management Committee meetings and reviewed the management plan. In contrast, the BLM and the Nature Conservancy recently hosted a Tecate cypress symposium convening experts and scientists. San Diego and Orange County land owners/managers and regional monitoring/management teams were invited in order to facilitate the exchange of information important for managing populations across the species distribution. These examples illustrate there could be opportunities for these stakeholders to collaboratively apply for grant funding, identify monitoring and management needs and information gaps, to develop consistent monitoring protocols, and to exchange information on the effectiveness of management actions. In this example, land owners/managers are responsible for implementing monitoring and management on their lands, but do so in a manner that is coordinated and consistent at both the reserve-wide and the South Coast Ecoregion scales. If there were sufficient interest and available resources, this collaboration could be expanded to include scientists, conservation practitioners, and land managers in Baja California, Mexico.

Tecate cypress serves as a host plant for the Thorne's hairstreak butterfly (*Callophrys [Mitoura] thornei*, Thorne's), a geographically isolated and ecologically distinct butterfly known only to occur on Otay Mountain in San Diego County. Thorne's is a BLM Sensitive Species and a covered species under the MSCP Plan. The native plant and animal communities on Otay Mountain have suffered from dozens of wildfires. For example, the Otay Fire of 2003 and Harris Fire of 2007 have created a primarily monotypic stand of Tecate cypress.

There are critical gaps in the ecology of this species. The status of Thorne's inside the MSCP is likely to be precarious, but is largely unknown. The amount of suitable habitat available to this butterfly is unknown, because its precise habitat requirements are unknown (Forister 2010). The restricted distribution of the butterfly renders it highly vulnerable to extirpation or extinction from catastrophic wildfire. Management and protection of the remaining few stands of Tecate cypress remains critical.

Various efforts on the part of SANDAG, BLM, USFWS, The Nature Conservancy, NROC and Conservation Biology Institute are underway to improve the knowledge of suitable habitat for Thorne's, as well as to understand the interactions between the butterfly and its larval host plant, Tecate cypress. Further collaboration to promote the continued viability and persistence of Thorne's and to inform the management and conservation of this species is warranted.

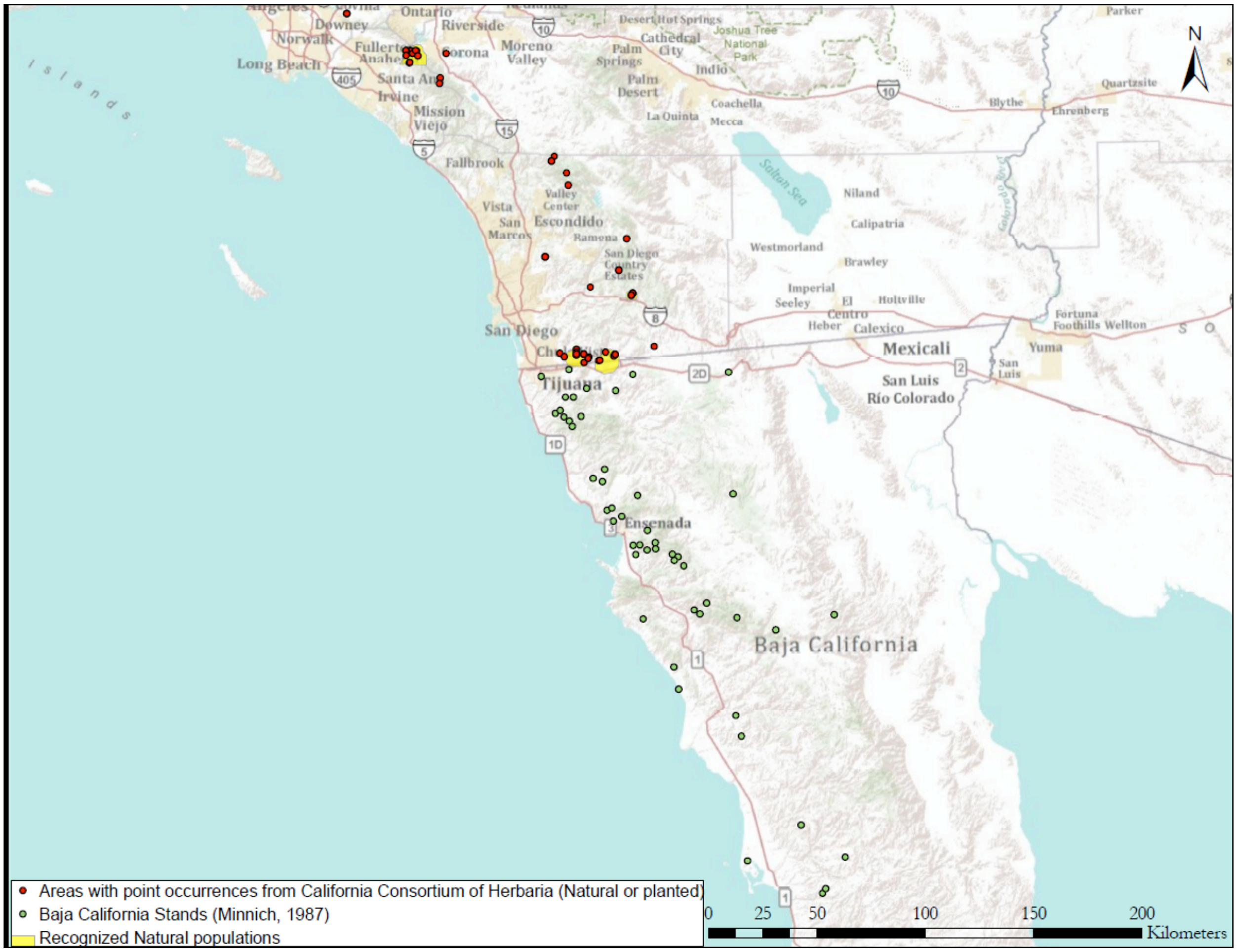

Figure 4. Distribution of Tecate cypress populations. Distributions are based on descriptions of Tecate cypress stands reported since 1948, and herbaria records (Consortium of California Herbaria 2009).

Summary and Recommendations

The use of spatial and temporal sampling strategies for collecting monitoring data on most ecological variables often improves the data quality while reducing costs and use of limited resources. Inventories of covered species populations will be based primarily on space-time sampling frameworks. Spatial sampling density will be dictated by cost factors and spatial variability of ecological variable being monitored and the desired statistical power for making decisions based on the data. Temporal sampling frequency will be determined by cost, power analysis and dynamics of the species or process being monitored. Our understanding of these spatial variability and temporal dynamics are limited; studies such as the Deutschmann team's assessment of floristic variability/dynamics provide insights into sampling requirements (cite ref). Similar empirical and meta-analysis studies are needed to determine space-time sampling requirements for priority covered species and threats/stressors. Maps, GIS data layers, such as the vegetation layer commissioned by SANDAG, which are derived through a combination of field sampling and interpretation of remote sensing imagery, can provide information on spatial and temporal variability that can inform spatial sampling designs (Curran 2001).

Regional monitoring is most effective when one entity implements it. The San Diego region should continue to move towards a fully functional regional management and monitoring entity that works with preserve managers and others in designing and implementing monitoring (including data analysis). To accomplish this unified approach monitoring would likely require funding agencies to pool resources or apply them in a coordinated fashion. This approach would help:

- Identify the spatial scale of monitoring by looking at the scale of threats and natural processes relative to the spatial distribution of the species or natural community targeted for monitoring
- Ensure monitoring is question driven
- Ensure monitoring efforts across jurisdictions is driven by the spatial scale of the organism and habitat
- Prioritize species and habitats for management, similar to the process undertaken for monitoring
- Use and refine conceptual models of target biological communities as a basis for recommending and prioritizing specific management actions for individual Preserve Areas.
- Ensure data from monitoring programs are analyzed in a timely manner so that insights into emerging trends can be used to alter management actions, funding

agencies and management decision-makers can make timely decisions affecting conservation outcomes, and timely feedback is provided on the consequence of management actions.

Appendix 1: Habitat Threat and Scale Matrices

Table 1. Matrix showing stressors, habitat type and the temporal scale of effect

	Recreation				Exotic Species	Wildfire		Roads	
	Hiking	Trail Riding	Biking	Dogs with hikers		Frequency	Intensity	Fragmentation	Unknown
CSS	ST	ST	MT	ST	LT	MT	LT	LT	MT
MSS	ST	ST	MT	ST	LT	MT	LT	LT	LT
Grasslands	ST	ST	ST	LT	LT	ST	ST	LT	ST
Riparian	ST	ST	ST	ST	LT	MT	MT	LT	ST
Chapparral	ST	ST	MT	ST	MT	ST	MT	LT	MT

ST = short term, less than 5 years
MT =moderate term, 5 to 10 years
LT = long term, more than 10 years

Table 2. Matrix showing stressors, habitat type and the spatial scale of effect

	Recreation				Exotic Species	Wildfire		Roads	
	Hiking	Trail Riding	Biking	Dogs with hikers		Frequency	Intensity	Fragmentation	Unknown
CSS	P/PS	P/PS	P/PS	P/PS	P	PS	PS	PS	R
MSS	P	P	P	P	P	PS	PS	PS	R
Grasslands	P/PS	P/PS	P	P/PS	P	PS	PS	PS	R
Riparian	PS	PS	P	P	PS	PS/R	R	PS/R	PS/R
Chapparral	PS	PS	PS	PS	P	PS	PS	PS/R	PS/R

P = Preserve
PS = Preserve System
R = Regional

Table 3. Matrix showing stressors, habitat type and the relative importance of concern

	Recreation				Exotic Species	Wildfire		Roads	
	Hiking	Trail Riding	Biking	Dogs with hikers		Frequency	Intensity	Fragmentation	Unknown
CSS	I	M	M	M	M	H	H	H	M
MSS	I	M	M	M	M	H	H	H	M
Grasslands	M	M	I	M	M	I	I	M	I
Riparian	M	M	I	M	M	I	H	M	M
Chapparral	I	I	I	I	I	M	H	I	I

I = Important
M = Moderately Important
H = Highly Important

Appendix 2: What is a threat/stressor?

The terms threats and stressors have often been used interchangeably in the literature. Others have suggested that the distinction between the two terms is illustrated by describing threats as the overarching term and stressor as the more specific causative term as illustrated by the following:

Threat: urban development

- Stressors
    - Lighting
    - Urban runoff
    - Argentine ant invasion
    - Fragmentation

Threat: Roads

- Stressors
    - Noise
    - Fragmentation
    - Direct mortality
    - Blockage of animal movement routs
    - Stream/river altered hydrology at bridges

Threat: Recreation

- Stressors
    - Noise
    - Fragmentation
    - Direct mortality
    - Disturbance of animal routines
    - Erosion and sediment

Threat: Wildfire

- Stressors
    - Food availability
    - Shelter

- Erosion and sediment
- Increased access to habitat by threats

Threat: Climate

- Stressors
  - Water
  - Food availability
  - Erosion and sediment
  - Increased access to habitat by threats
  - Increased potential for wildfire
  - Increased pests

This hierarchical classification is useful for many threats but not all; nor is it for the purposes of this discussion. The term threats/stressor as utilized herein is intended to be inclusive rather than implying any hierarchical classification of the two. Threats/stressors are also identified as risk factors in the literature. There are multiple definitions of these terms in the literature including the following:

- “an action that imposes changes on an ecological system,” (US Naval Guidelines, Ecological Risk Assessments, 2006 at http://web.ead.anl.gov/ecorisk/index.cfm)
- “factors that disrupt equilibrium and include both natural processes and the human activities that exert stress on natural communities,” (Chicago Region Biodiversity Council, 1999).
- “the activities or processes that threaten the viability of populations and cause negative trends in population size,” (Regan et al 2006)

Appendix 3: Definitions

Covered species – species identified for regulatory coverage in the San Diego MSCP and MHCP plans.

Drivers – environmental parameters that most regulate the system/population

Ecoregion – a large unit of land containing a geographically distinct assemblage of species, natural communities, and environmental conditions

Effect – result of a stressor on one or more individuals

Flagship species – iconic animals that provide a focus for raising awareness and stimulating action and funding for broader conservation efforts

Planning Segment/Unit – group of parcels/preserves that need to be managed together, regardless of ownership

Preserve – individual unit managed by one entity

Reserve System – collection of individual preserves and/or planning units across a region – openspace infrastructure

South Coast Ecoregion – includes portions of five counties in Southern California (Los Angeles, San Bernardino, Riverside, Orange, and San Diego) that support coastal sage scrub habitats.

Stressors – anything that causes a change to an environmental parameter or resource that is important to the species or individual of interest

Subarea – defined principally as individual jurisidictions (e.g., cities or utility districts) within San Diego's Subregions

Subregion – defined principally by political boundaries and is the scale at which individual multiple species planning efforts are conducted. Subregions of the South Coast Ecoregion include MHCP, MSCP, NC MSCP, and EC MSCP in San Diego County; Southern and Central-Coastal in Orange County; Western Riverside MSHCP, Palos Verdes, and Western San Bernardino (not active)

Target species – those species having an ability to represent the ecoregion and relating to the overall protection of ecosystem health and other species sharing the same habitat and threats

Threat – effect of a stressor at the species scale, not individuals

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